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Autonomous inspection of underwater structures

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HIGHLIGHTS

- Underwater inspection for a safe and secure harbor and AUVs reduce the costs.
- Basic tasks: find the object, approach and follow until whole area is covered.
- The pier walls are described as lines in the horizontal plane.
- Wall following algorithm with x-track error control is used.
- Adaptive path planning considering the sensor constraints to fully cover the area.

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ABSTRACT

In the future our resource on land will be over exploited. The exploration of new resources in the ocean is in progress. Mining will be done on the bottom of the sea. The sea is also a big source of renewable energy. Off shore wind parks and tide plants are built. Also, the major world trade is handled over sea routes and several big harbors. All this maritime facilities are getting older and there are effects like corrosion or malfunctions. In general, they need to be inspected frequently. For deep sea applications, security reasons and cost reduction autonomous underwater vehicles (AUVs) will be the first choice.

The project "CView" addresses one of these inspection problems, the harbor inspection. But the algorithms, we present in this article can be adapted to many other inspection tasks. One of the main goals in this project is to find cracks or damaged areas at the underwater buildings or to observe critical sections under water with cost effective methods.

The platform for developing the guidance algorithms for inspection is the AUV "SeaCat". This underwater vehicle has a control software system with an user interface for mission planning, a mission control system, a precise navigation system, optimized motor control with an autopilot and sensors for obstacle detection and inspection.

For obstacle and inspection target detection, a scanning sonar is used. The sonar images are automatically processed with edge detection and line extraction algorithms to get a simplified environment description, which is used by the guidance methods presented in this article. A pan–tilt enabled sensor head with camera, laser measurement and MBES (Multi Beam Echo Sounder) is used to inspect the detected objects. Additionally, these sensors provide distance information to the inspection object which can be used by the inspection guidance.

This article presents methods for inspection using the online information from the vehicle sensors to guide the vehicle efficient and safely. It is also important to handle the interaction between mission planning and execution. During mission planning, the operator will define the type of the inspection object (wall, vessel, sluice, etc.). The algorithms we develop use the information from the mission planning and the online data from the vehicle sensors to guide the vehicle to get the optimal inspection results. Therefore, a precise distance control to the inspection object, collision avoidance and object recognition are needed.

1. Introduction

Autonomous underwater vehicles gain more importance now and in the future [1]. Nowadays, they are mostly used for exploration and other scientific applications. Sometimes they are also used for simple inspection tasks, which are mostly surveys similar to exploration tasks.

The inspection of buildings, machines, etc. has been a very common task in our world for a long time. To operate a machine a lot of regulations exist, like for any kind of man made objects. These regulations intend to provide safety and functionality of these devices.

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Some of these objects are underwater constructions or floating objects like vessels or offshore working platforms. Underwater constructions can be harbor facilities, offshore drilling or pumping platforms, offshore wind park foundations, reservoir dams or sluices, etc. All these things need regular inspection to detect damages or corrosion. Also, the hulls of ships need inspection to discover leakages or smuggling goods. Most of these areas are difficult to reach and expensive to monitor frequently.

Usually, these inspections were done with divers and/or remotely operated vehicles (ROVs). Unfortunately, divers need special training and the diving assignments are often dangerous. The usage of ROVs needs a crew onshore or on a mother-ship which is operating the ROV during the complete mission. Therefore, the ROV needs a steady communication with the operator through a cable. The operating crew has to pay a lot of attention to control every movement of the vehicle and to examine the sensor data.

To minimize the personal and financial effort and to be able to do regular inspections, routine tasks need to be automatized. ROVs improve the security and also minimize costs but they need an operating crew and the communication cable. It cannot operate freely like divers. The use of an AUV can reduce the manpower needed for the same work done by an ROV by around 50% to operate the vehicle and for logistics [2].

Autonomous operating vehicles can do the routine tasks and they do not require the cable connection to an operator; they operate and maneuver in their environment freely. Solutions with autonomous underwater vehicles (AUVs) exist for unstructured or less structured environments. They are comparable to sea bottom exploration tasks. Mostly, a predefined path is followed and distance to possible dangerous objects is kept. The challenge is the maneuvering in complex environments like harbors and operating in short distance to the inspection object, which is needed for visual inspection. This can be done by ROVs, but with the described limitations. An example for the use of AUV for under water inspections is the HAUV project [3,4], which is able to inspect ship hulls using a DIDSON sonar and a Doppler log DVL for navigation relative to the ship. The Project "CView" has the goal to inspect underwater structures in harbors in visual range with AUVs. This article describes the vehicle guidance in harbor environments for inspection tasks.

Fig. 1. Typical harbor, Hamburg Harbor [6].

Fig. 2. Surface damages [7].

Fig. 3. Laminar corrosion [7].

2. Inspection

"Underwater inspection is the continuation of the onshore fabrication of a facility through shipment, installation, to operation. It is first required during installation and then periodically when the facility is operational" [5, p. 23].

Inspection is generally the assignment to monitor the actual state of an object, machine or construction. Due to the inspection results maintenance can be planned, also the time for the replacement of the inspected object when required. Regular inspection will detect failures in an early state, but inspection itself is not gratis. A balance between the maintenance costs and the inspection costs has to be found. Additionally, safety issues have to be considered for planning and execution of the inspections, while automatic inspections will reduce the costs.

2.1. Harbor inspection

Harbor facilities need regular inspections for damages and corrosion. The constructions which are not underwater are easily reachable, but the underwater constructions can only be reached by divers or when the water is removed. Usually, the underwater constructions of harbors are inspected for damages, which can be: collision of vessels with the piers, scouring on walls, piers or corrosion on walls or sheet pile walls. Different damages are shown in Figs. 2 and 3.

Collisions and known damages are examined and observed by divers and ROVs as mentioned in the introduction of this article. Unknown damages are difficult to be discovered by these instruments. Often, large areas have to be examined regularly; but therefore specially trained personnel are expensive. When using divers, the inspected areas have to be restricted. The communication and power cable of ROVs is a problem for the traffic in the harbor.

Fig. 1 shows a typical harbor with its basins and traffic routes. It is easy to recognize the problem of an extensive and regular inspection.

The common behavior of AUVs is the automatic path following of the planned tracks and the recording of the sensor information. The analysis of the data can be done online by the vehicle or post-mission. The post-mission analysis can be done manually by the operator or automatically. The advantage of online damage detection is that the AUV can approach the interesting area a second time and examine it in detail.

3. Hardware platform

The used vehicle for the inspection will be the AUV "SeaCat" (Fig. 5) built by ATLAS ELEKTRONIK (AE). It is developed on the experience gained with the AUV "SeaWolf"; also developed by AE.